WALNUT RIVER BASIN TOTAL MAXIMUM DAILY LOAD

Water Body: Winfield City Lake
Water Quality Impairment: Eutrophication

Subbasin: Lower Walnut **County:** Cowley & Butler

HUC 8: 11030018 **HUC 10** (HUC 12)**: 03** (02,03)

Drainage Area: 64 square miles in Timber Creek Watershed

Conservation Pool: Area = 1070 acres, Maximum Depth = 12.5 meters

Designated Uses: Primary Contact Recreation (A); Expected Aquatic Life Support; Domestic Water Supply; Food Procurement; Industrial Water Supply; Irrigation Use; Livestock Watering, Groundwater Recharge

303(d) Listings: 2004 Walnut Basin Lakes, Eutrophication; 2008 Walnut Basin Lakes, Eutrophication

Impaired Use: Primary Contact Recreation and Domestic Supply uses are impaired/threatened

Water Quality Standard: Nutrients - Narrative: The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the production of undesirable quantities or kinds of aquatic life. (KAR 28-16-28e(c)(2)(B)).

Suspended Solids – Narrative: Suspended solids added to surface waters by artificial sources shall not interfere with the behavior, reproduction, physical habitat or other factor related to the survival and propagation of aquatic or semi-aquatic or terrestrial wildlife. (KAR 28-16-28e(c)(2)(D)).

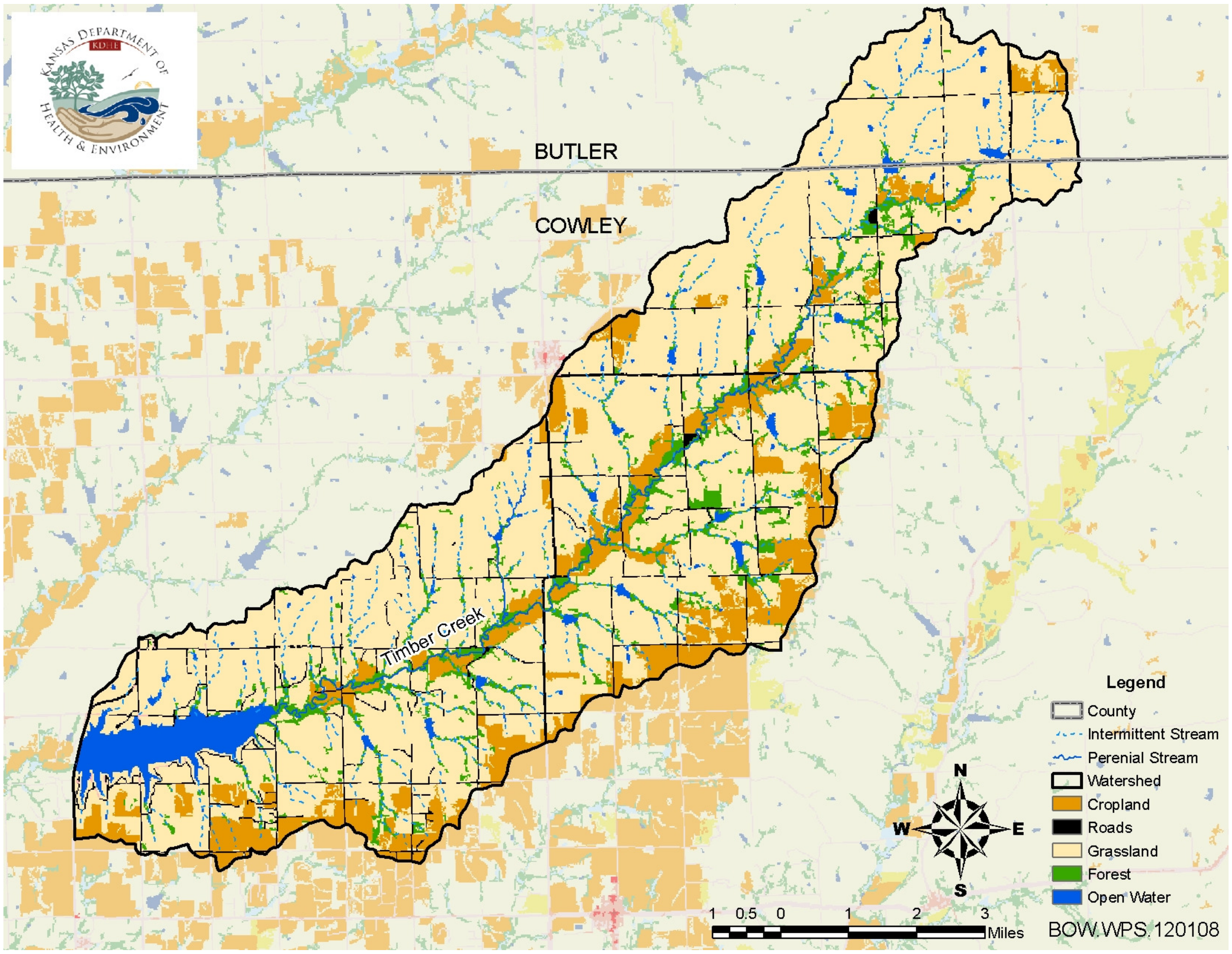

Figure 1- Land uses in the Winfield City Lake watershed. The headwaters of Timber Creek are in southern Butler county, and the majority of the watershed lies within Cowley County. Timber Creek and Winfield City Lake are the only waters in this watershed on the Kansas Surface Water Register.

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Dam Closure: 1971

Monitoring Sites: Station LM050801 in Winfield City Lake. (Figure 1)

Period of Record Used: Six surveys from 1988 to 2005.

Current Condition: During the monitoring period the lake has typically more than 7 mg/l dissolved oxygen in the top 5 meters of the water column (Figure 2), and surface pH has averaged 7.8. Average chlorophyll A at the surface has been 11.8 ppb. Secchi depth has ranged from 0.35 to 1.5 meters (Figure 3). TSS has averaged 12.7 mg/l. Epilimnetic total nitrogen has averaged 0.48 mg/l and epilimnetic total phosphorus has averaged 0.038 mg/l.

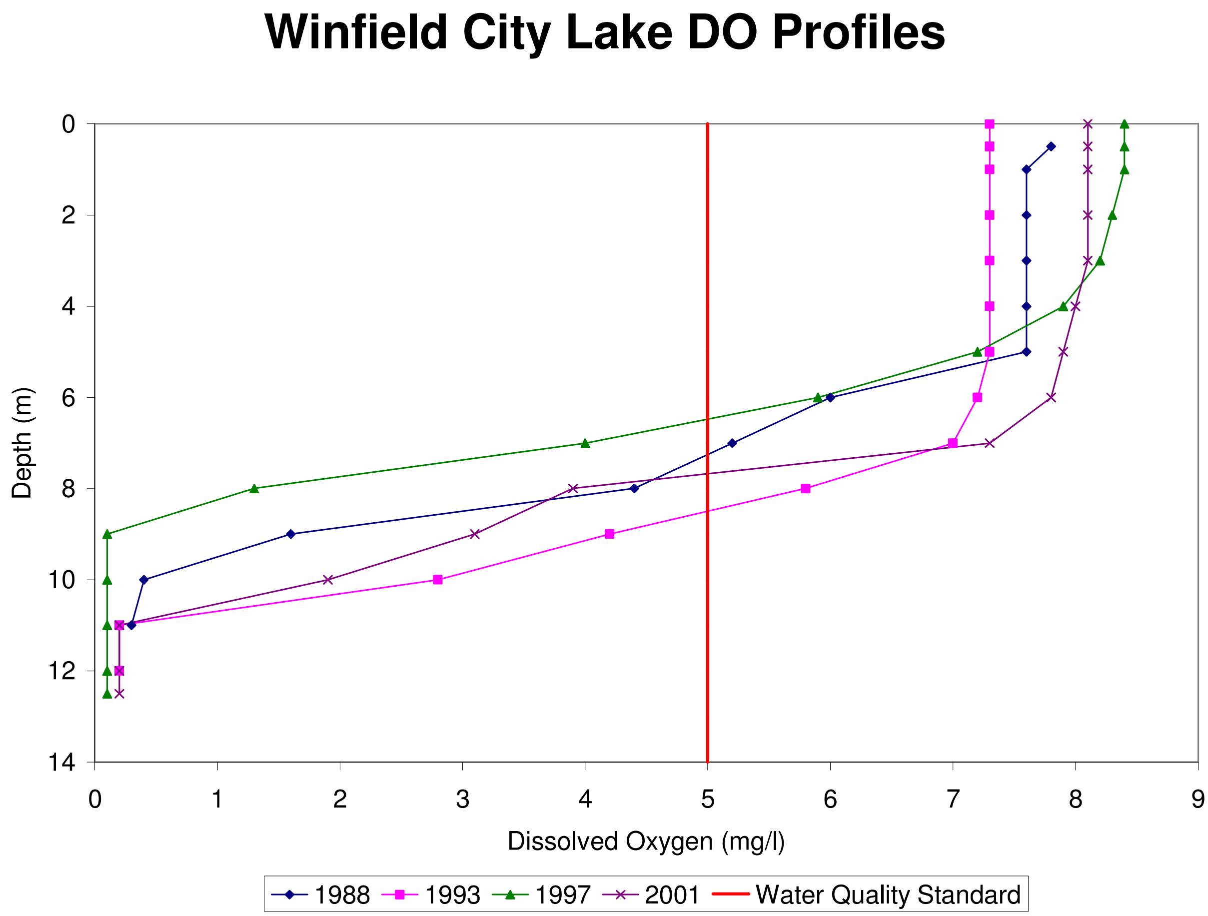

Figure 2- Dissolved oxygen profiles for the four sampling events from 1988-2001. In 1989 and 2005 low water levels prevented boat access, so no dissolved oxygen profiles were conducted. Metalimnion typically occurs in this water body at approximately 5 meters depth from the surface.

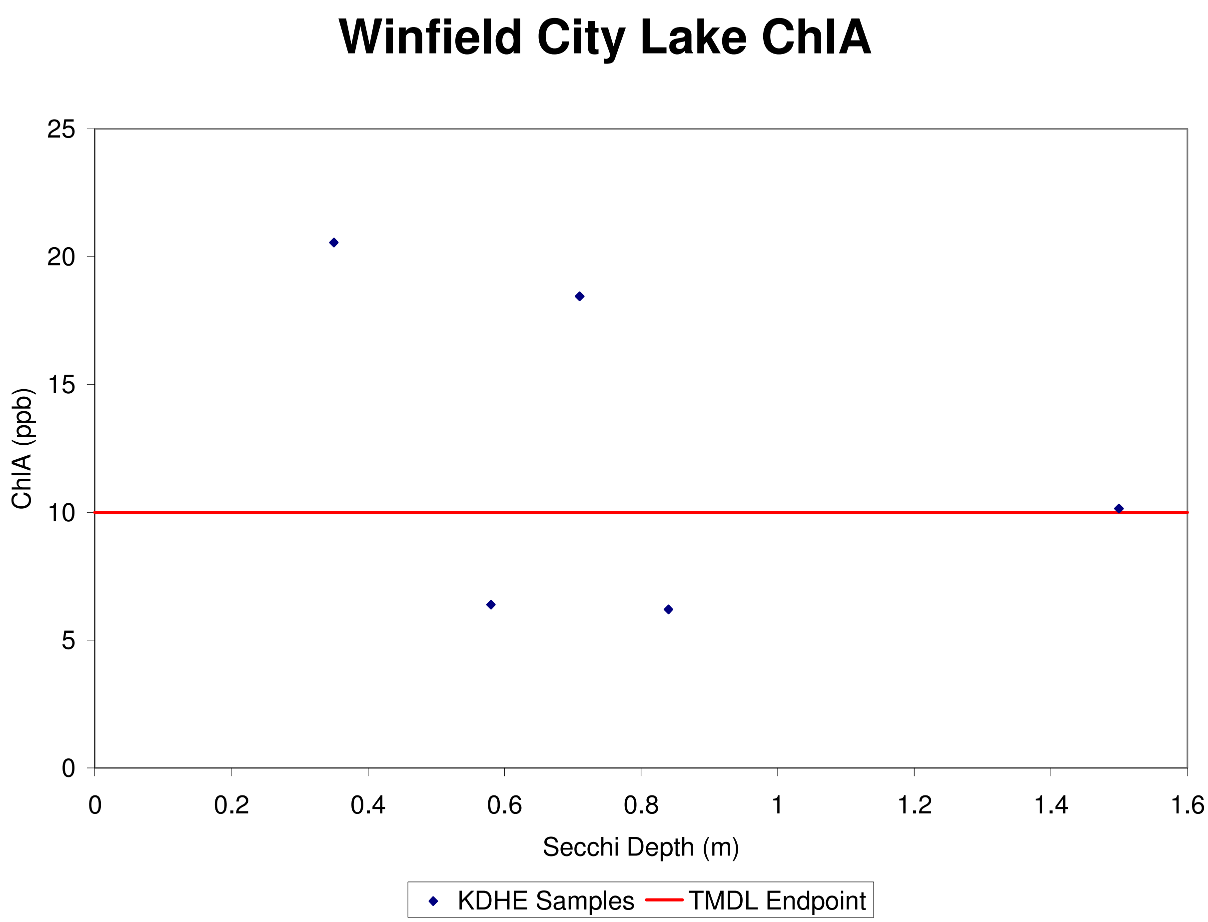

Figure 3- Secchi depth and chlorophyll A concentrations do not appear to be linked in this water body at the present time.

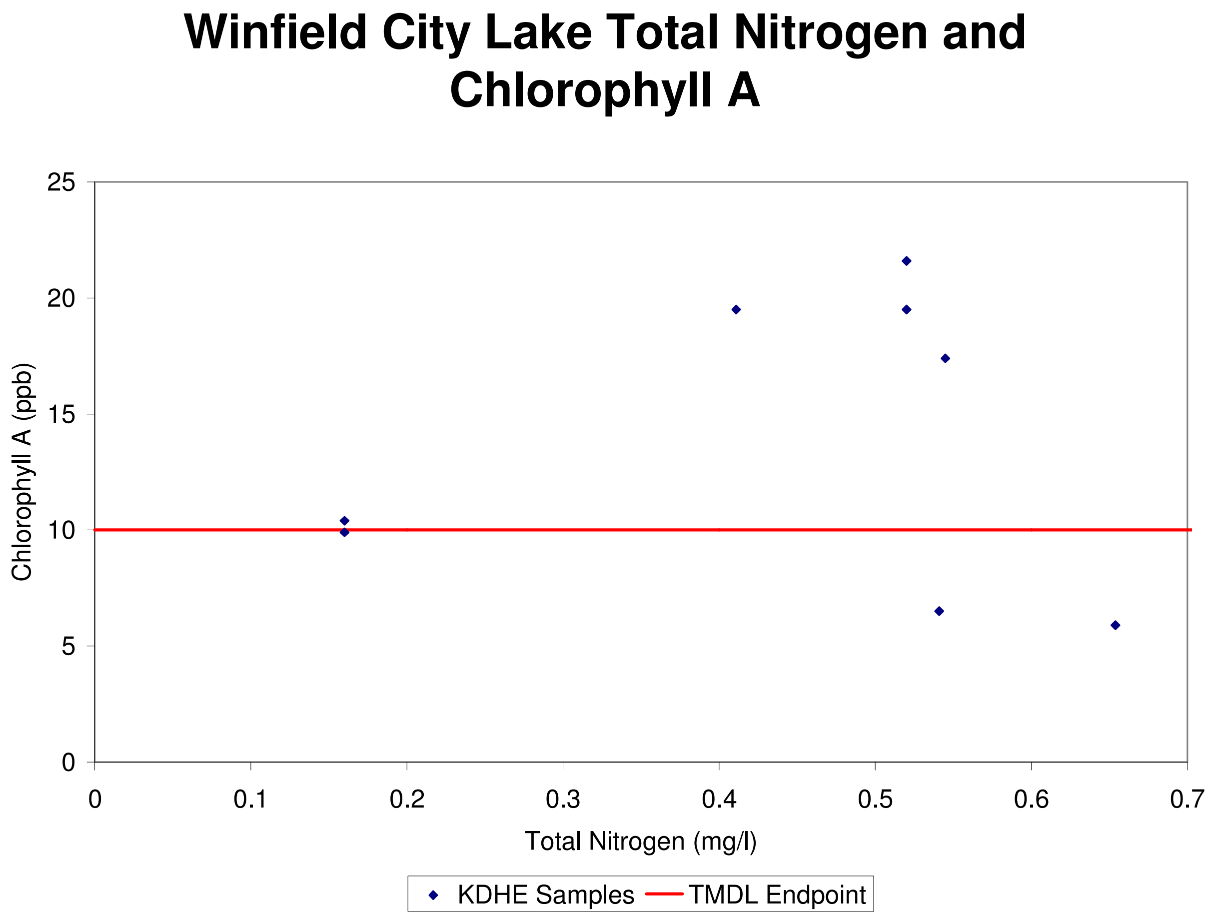

Figure 4- Chlorphyll A concentrations in Winfield City Lake as a function of the total nitrogen concentrations during time of collection.

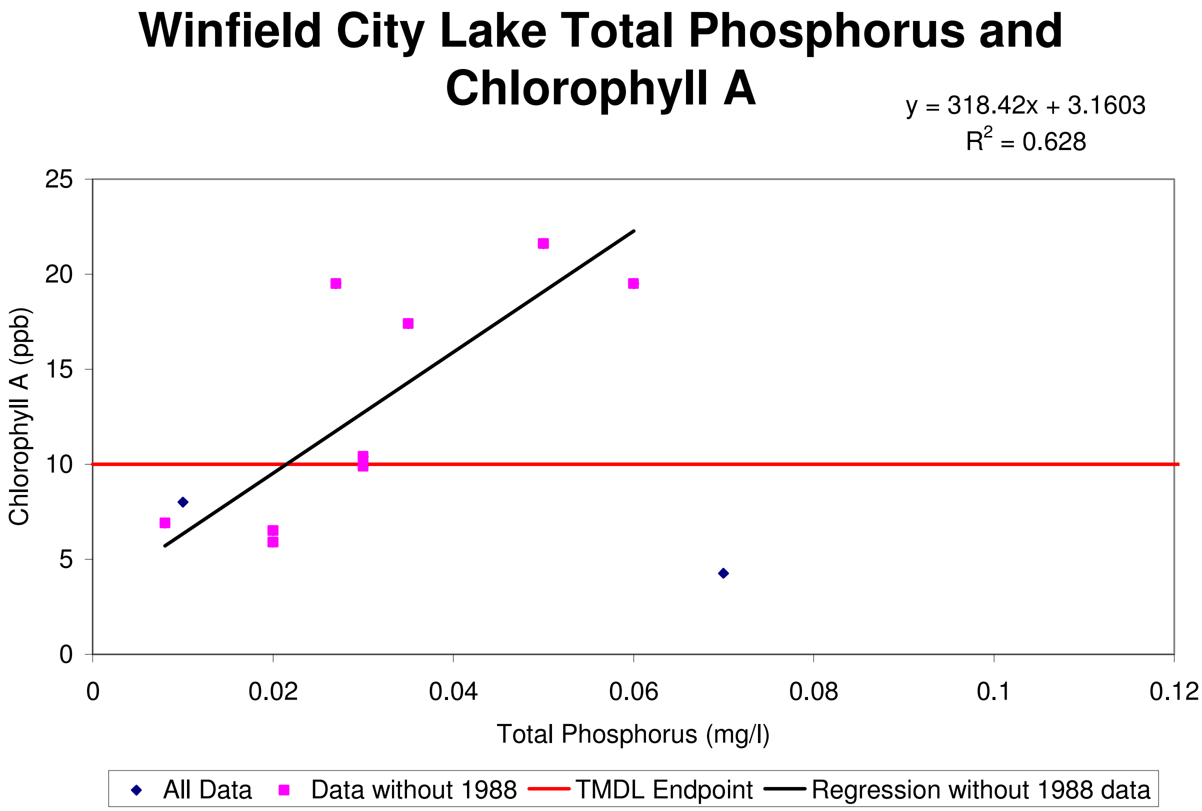

Figure 5- Chlorophyll A concentrations in Winfield City Lake as a function of total phosphorus concentration at time of collection. The 1988 pair of duplicate samples showed widely differing TP concentrations, however linear regression model of the remaining data suggests a strong ChlA response to increases in TP in this waterbody.

Sample Date	Chlorophyll A (ppb)	TN (mg/L)	TP (mg/L)	Secchi Depth (m)	Turbidity (NTU)	TSS (mg/L)
7/27/1988	6.13	NA	0.04	NA	4.95	8.5
8/5/1989	6.9	NA	0.008	0.58	NA	NA
8/3/1993	20.55	0.52	0.055	0.35	16	20.5
8/4/1997	10.15	0.16	0.03	1.5	2.35	3.5
6/26/2001	18.45	0.478	0.031	NA	9.35	16
7/25/2005	6.2	0.5975	0.02	0.84	12.35	12.5

Table 1- Table of average epilimnetic water quality data for major parameters as monitored by KDHE at Winfield City Lake. Fields marked NA were not measured.

In December of 2006 zebra mussels were confirmed in Winfield City Lake. While we currently have insufficient evidence to determine what impacts will accrue to this waterbody from the zebra mussels, previous experience has indicated that significant water quality impacts are likely.

Interim Endpoints of Water Quality (Implied Load Capacity) at Winfield City Lake over 2008 - 2012: This TMDL shall serve primarily as a protection measure to ensure that the threatened uses are protected and that the lake will continue to serve its designated uses. Therefore, the interim endpoint shall be reflective of primary contact recreation and drinking water supply uses and is chlorophyll A less than 10 ppb.

3. SOURCE INVENTORY AND ASSESSMENT

Land Use: Land use in this watershed is predominantly permanent grassland, with significant localized areas of row crop production (Figure 1, Table 2). Riparian zones along perennial streams are largely buffered by permanent vegetation (Table 3,4). Low sloping areas in the alluvial valley of Timber Creek are predominantly cropland outside of the buffered zone.

Land Use Type	Percentage of Watershed
Permanent Grass	71.5%
Cropland	13.4%
Forest	5.6%
Water	4.1%
Roads	3.9%
Wetland	1.5%

Table 2- Land use in the Winfield City Lake watershed extracted from the 2001 National Land Cover Dataset.

Land Use Type	Percentage of Watershed
Permanent Grass	5.6%
Cropland	12.0%
Forest	38.6%
Water	2.3%
Roads	3.0%
Wetland	38.5%

Table 3- Land use in a 33 meter buffer adjacent to perennial streams in the Timber Creek watershed. Ibid.

Land Use Type	Percentage of Watershed
Permanent Grass	14.8%
Cropland	29.2%
Forest	27.1%
Water	2.7%
Roads	4.5%
Wetland	21.8%

Table 4- Land use in a 100 meter buffer adjacent to perennial streams in the Timber Creek watershed. Ibid.

The Kansas Biological Survey (KBS) conducted a bathymetric survey of Winfield City Lake in late 2007 (Figure 6). 14,790 individual depth points were collected. Data from this survey and a digitized upper boundary of the lake drawn from the National Agricultural Imaging Program (NAIP) 2004 photographs (Figure 7) were combined in a single point file. Boundary points were assigned an elevation of conservation pool (1,256.3’ above sea level). The point file was converted into a triangulated irregular network (TIN) to represent the current bottom surface of the lake (Figure 8).

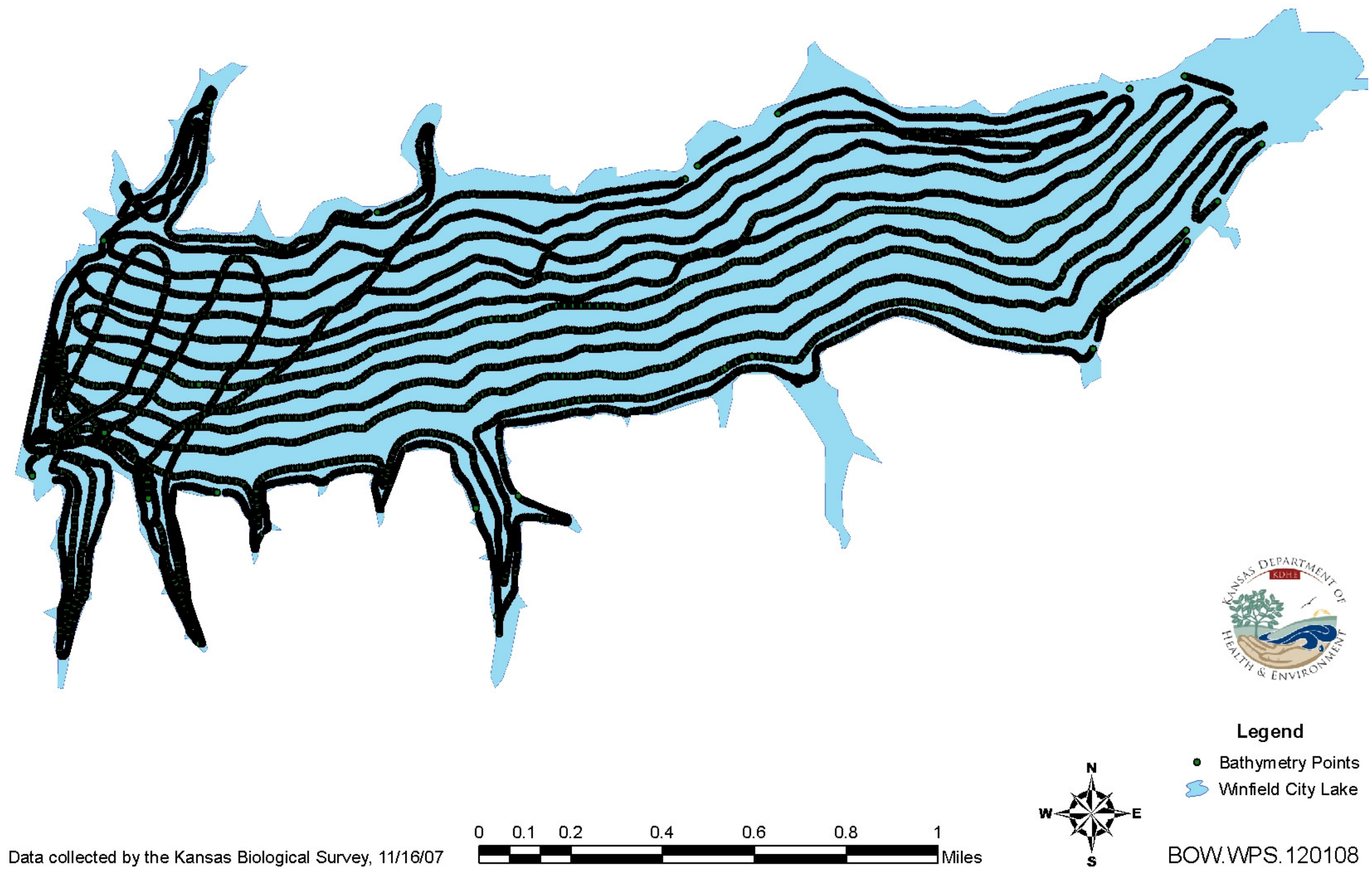

Figure 6- Bathymetry data collection points from Kansas Biological Survey. Most points are indistinct at this spatial scale. 14,790 individual points are shown.

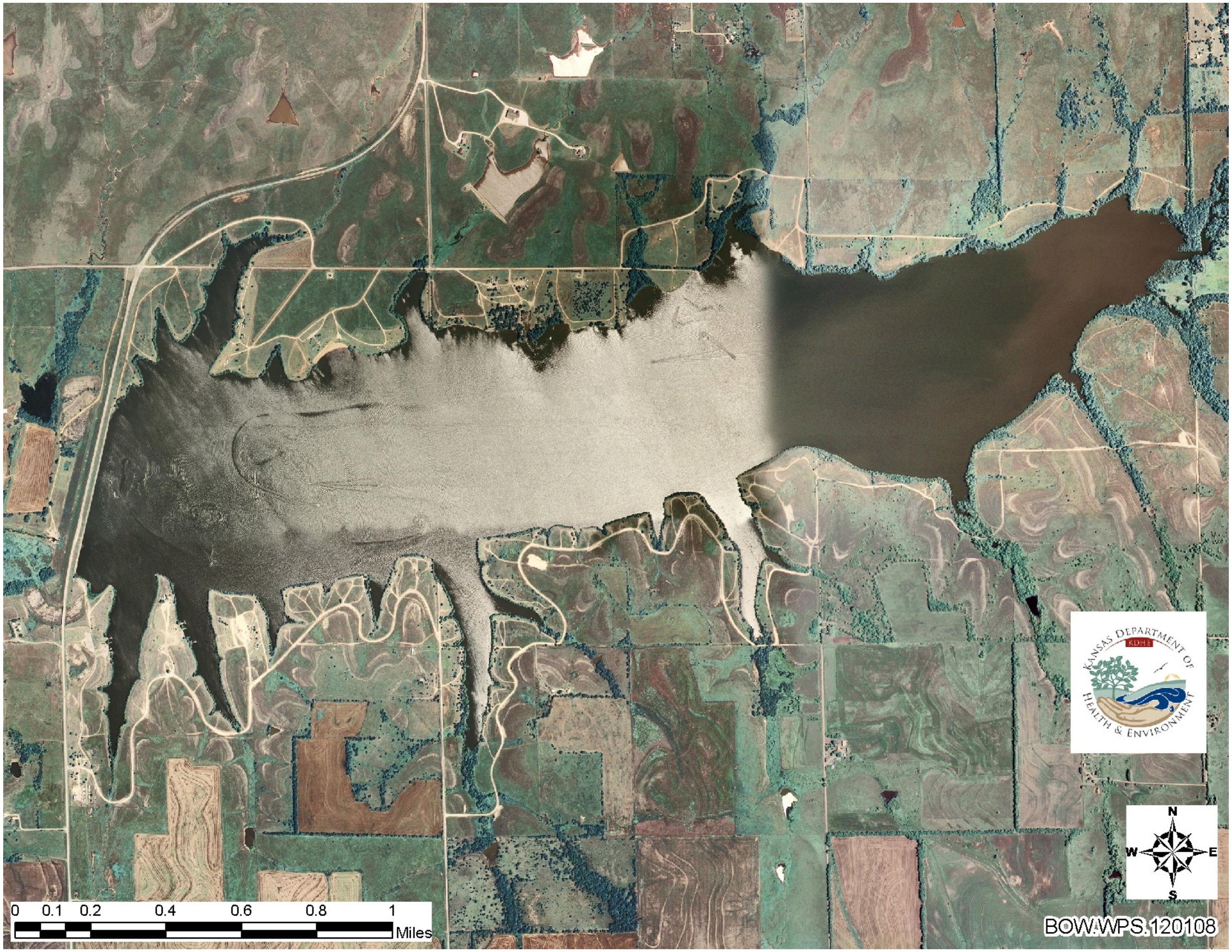

Figure 7- National Agricultural Imaging Program (NAIP) 2006 aerial photographs of Winfield City Lake

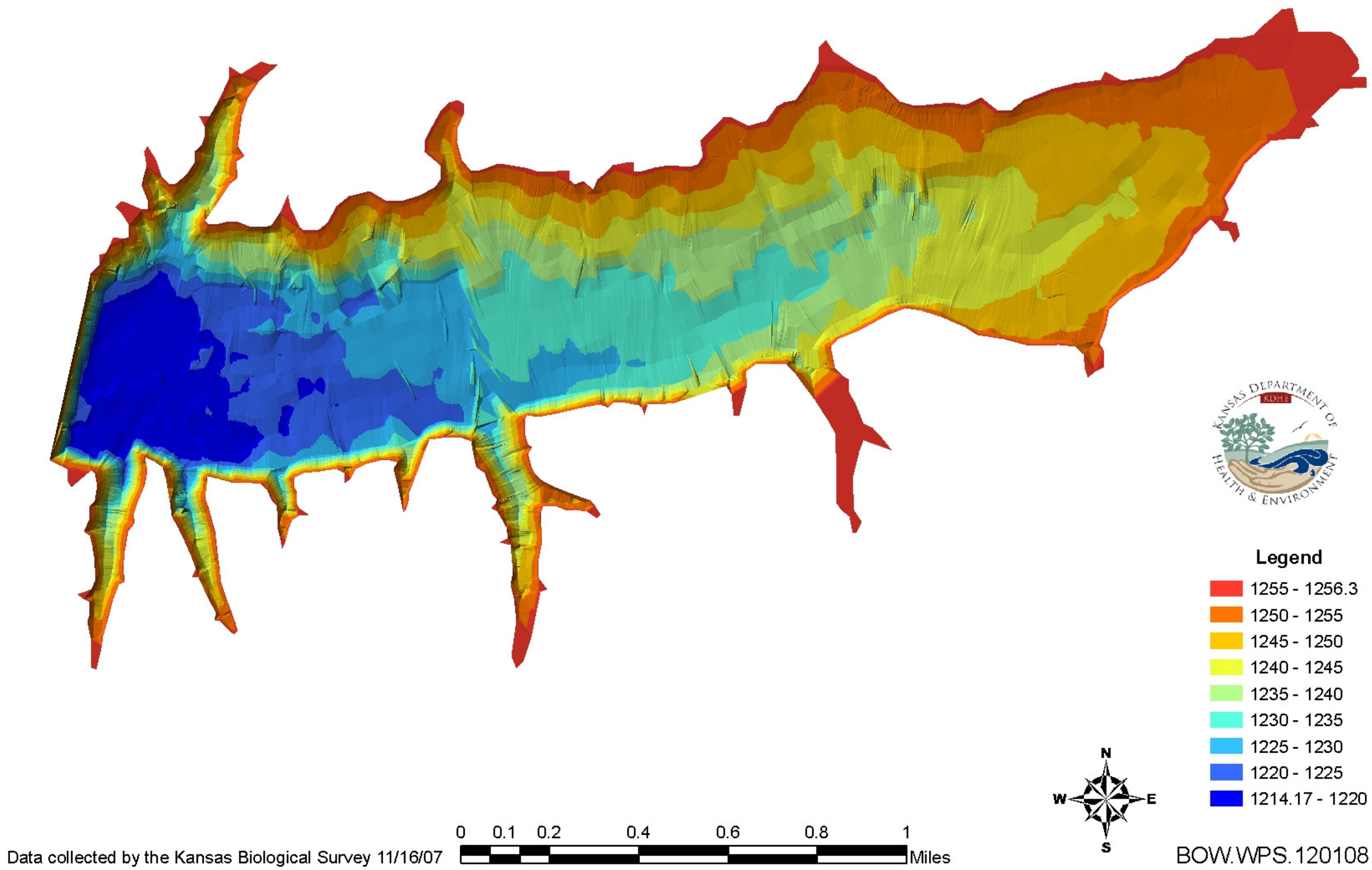

Figure 8- A triangulated irregular network (TIN) of the elevation above sea-level in feet of the bottom of Winfield City Lake.

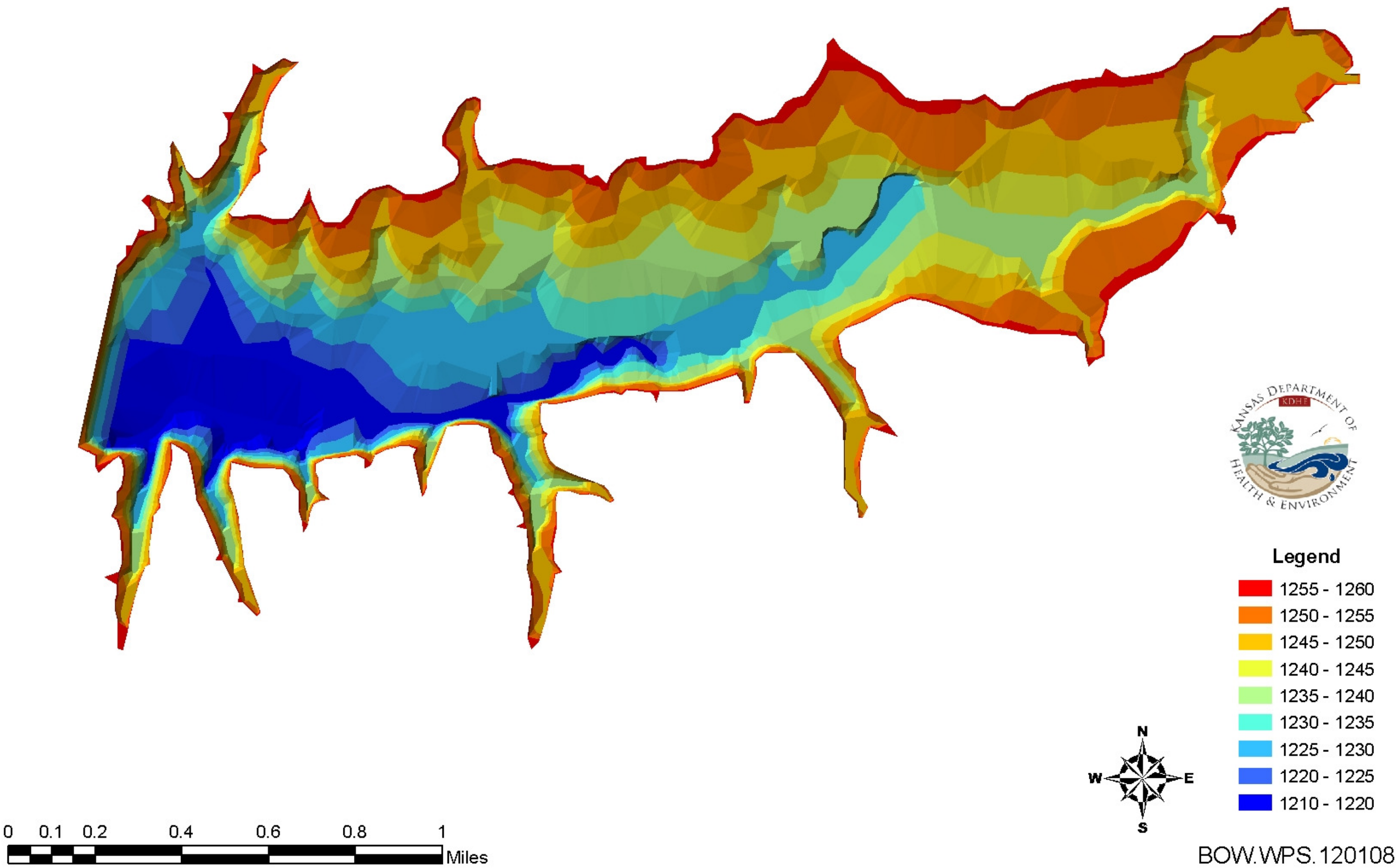

Figure 9- A triangulated irregular network (TIN) of the elevation of the valley floor impounded under Winfield City Lake at the time of dam closing, in feet above sea level.

United States Geological Survey 10’ topographics maps predating the impoundment of Timber Creek to form Winfield City Lake were digitized to provide a baseline estimate of volume loss. Where necessary the 1250’ line was moved to fall within the current boundary of the lake, all other lines were digitized to the face of the dam and connected across the valley. Lake boundaries were assumed to have changed little, and the upper limit contour line was established as the current lake boundary at conservation pool. Contour lines were then converted into a TIN (Figure 9) to estimate pre-impoundment potential storage capacity.

Original design documents were consulted to determine the level of borrow needed for the construction of the dam, and the approximate location that borrow soil was taken from. The designated borrow area was low in the valley, near the current dam location.

The KBS survey data shows that the lake has a current capacity at conservation pool of 17,921 acre feet of water. Surface area is 1,070 acres, and the average depth is 16.75’. When adjusted for soil removed during the construction of the dam, borrow pits and other purposes, the pre-impoundment capacity was estimated at 18,634 acre feet of water at conservation pool. Surface area is unchanged, and pre-impoundment average depth was estimated at 17.4’ (Table 5). Total estimated lost storage capacity (713 acre feet) was divided by the years since the dam closed (36), to estimate annual sediment loading. On an average basis, 20 acre feet of sediment enter Winfield City Lake each year, though it’s likely that most of the load arrives during a few large storm events that are unevenly distributed through the years. At this rate Winfield City Lake will be completely full in 905 years, or around 2912 A.D (Figure 10).

	Volume (acre feet)	Surface area (acres)	Avg. Depth (feet)
Current	17921.2	1070.0	16.7
Pre-impoundment	18633.9	1070.0	17.4
Change	712.7	0.0	0.7

Table 5- Summary capacity data for Winfield City Lake before the dam was constructed and currently.

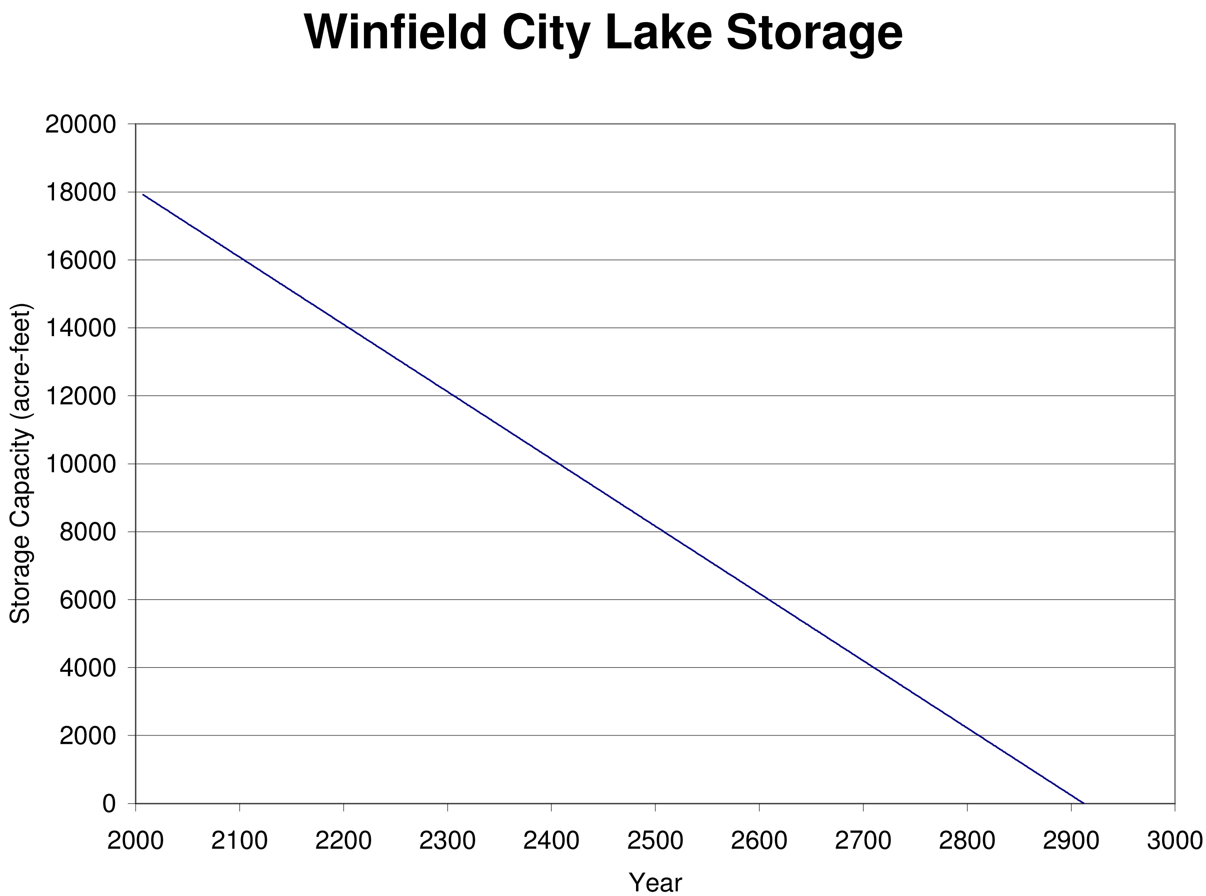

Figure 10- A linear approximation of projected storage by year assuming current rates of sedimentation continue. This waterbody is estimated to have 905 years until the entire conservation pool is filled with sediment. Useful storage life as a water supply reservoir is likely to be much shorter.

The pre-impoundment TIN and the KBS data TIN were converted to a continuous raster file format to determine the spatial distribution of the changes in water depths since impoundment. Pre-impoundment elevation was subtracted from current elevation of the bottom. The results (Figure 11) suggest that a number of identifiable changes have occurred. Areas in orange and red show increases in the depth of the lake, while green to blue areas are locations where the lake depth has decreased since impoundment. A number of areas of apparent sloughing are visible in the western end of the lake, where sediment has likely moved down to lower elevations in the lake. The historic channel shows some signs of filling, with the most concentrated areas in the lowest portions of the pre-impoundment valley. There also appears to be a delta forming at the outlet of Timber Creek into Winfield City Lake at the eastern most end. 2002 Digital Orthoquad (DOQQ) photographs were taken during a dry period, and show some of the mud flats that are forming in these upper reaches (Figure 12). These maps are unable to show changes the accurately reflect the borrow area used for the construction of the lake, because survey data for the elevations after the borrow was completed were not available to us.

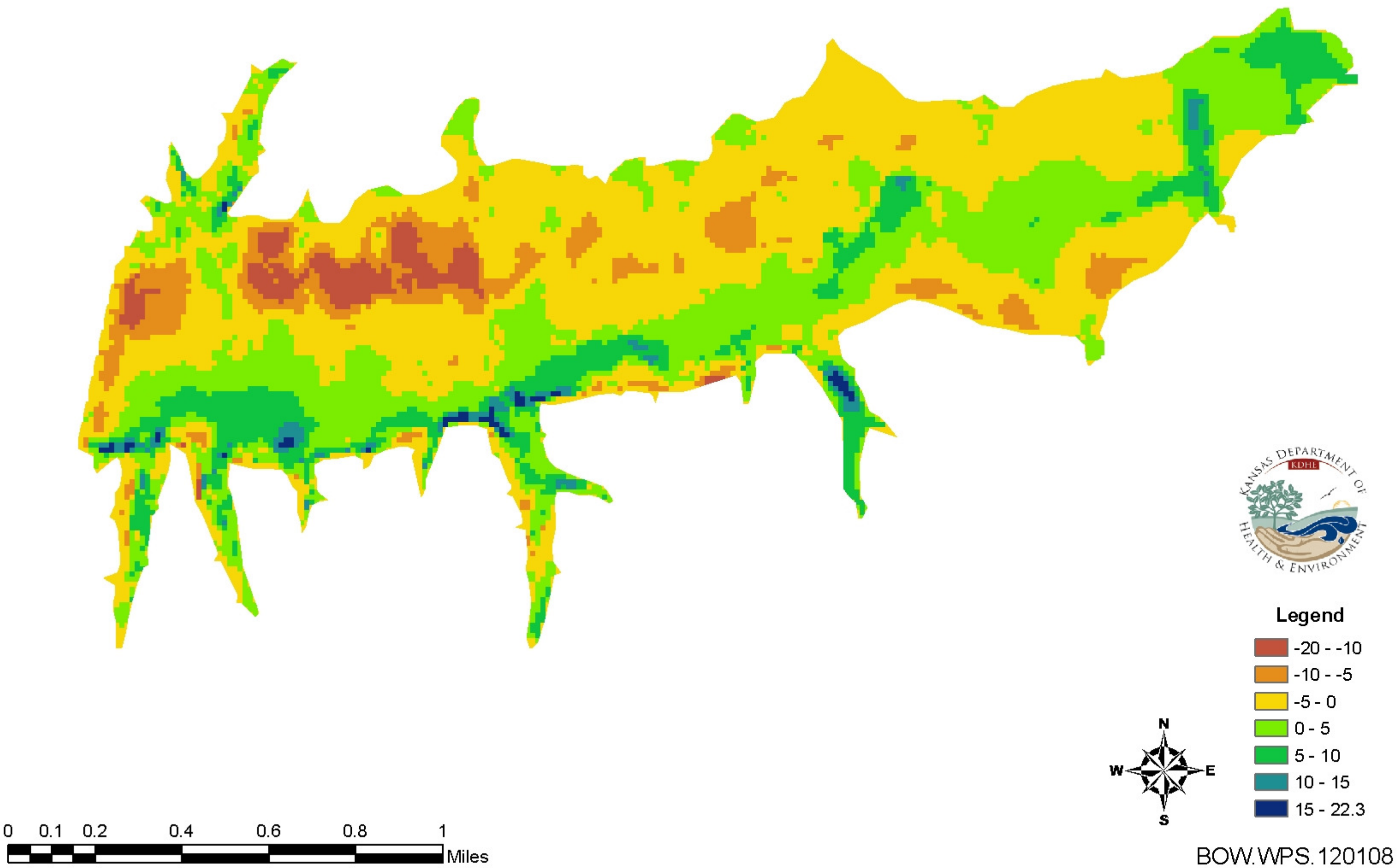

Figure 11- Changes in depth in feet from the time of closure through the fall of 2007. Some error is present due to the lack of accurate post-borrow, pre-impoundment surveys in the lower reaches of the lake.

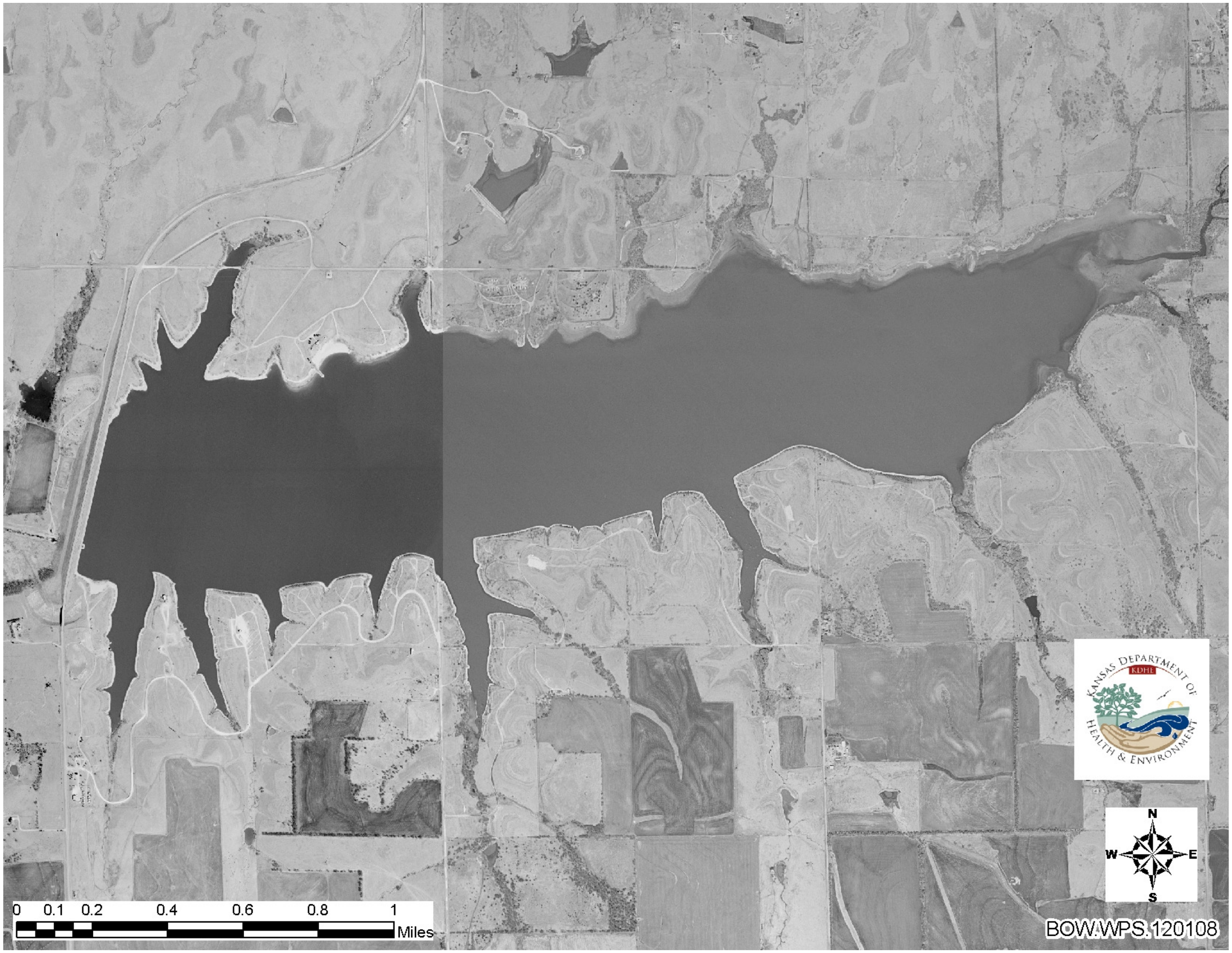

Figure 12- 1 meter resolution aerial photographs of Winfield City Lake taken during a low water period. Visible in the upper end of the lake is a small delta forming from deposited sediment. Images from 2002 DOQQ.

A BATHTUB model was used to estimate phosphorus loading to Winfield City Lake. Calibration and model source data are detailed in Appendix D. Model results suggest that on average the annual load of total phosphorus to this lake is 7,225 pounds. This level of loading corresponds to a 12 ppb average cholorophyll A concentration and an average phosphorus concentration of 38 ppb. A STEPL model was used to compare watershed loading potential. STEPL results were similar to BATHTUB results, with an estimated 7,367 lbs/year load. Details of STEPL calibration are included in Appendix D.

Winfield City Lake TP Load Current Conditions	Lbs/year
Permitted Dischargers	0
Atmospheric Deposition	95
Non-point Source	7,130
Total Annual Load	7,225

Table 6- BATHTUB modeled current total phosphorus loading to Winfield City Lake

The calibrated BATHTUB model was used to estimate the needed load reduction to achieve acceptable water quality. A reduction of the average chlorophyll A concentration to 10 ppb is expected to assure attainment of water supply uses. A 25% reduction in total phosphorus, corresponding to an annual load of 5,419 pounds is expected to result in chlorophyll A concentrations of 10 ppb and an average phosphorus concentration of 32 ppb. Further reductions of phosphorus loads below this level will likely lead to even better conditions in the lake. Load allocations are shown in table 6.

Internal Loading: BATHTUB calibration showed that the expected impact of internal loading was low. Calibration results are included in the appendix. The calibrated model makes no assumption of internal nutrient loading, due to the lack of any data from this lake on this potential source. Some resuspension of the sediment in the eastern end of the lake may be occurring due to wave action from personal watercraft use. Because Winfield City Lake is phosphorus limited, a reduction in resuspension may positively impact the quality of water in this lake, as phosphorus is often physically attached to sediment.

Other Sources: No permitted dischargers or non-discharging permitted facilities exist within the watershed. Some nutrient flux may originate with livestock on range with access to surface waters in the watershed. Some shoreline erosion has been noted in the main pool of Winfield City Lake. These source are likely small overall contributors to the observed concentrations in this waterbody.

Background Levels: Some of the land in the watershed is woodland; leaf litter may be contributing to the nutrient loading. The nutrient recycling, atmospheric deposition, and geological formations (i.e., soil and bedrock) may contribute to phosphorus loads.

Critical Conditions/Seasonality- Because eutrophication related impairments to drinking water supply uses are most likely to occur during summer months due to warmer temperatures and greater photosynthetically available radiation, summer monitoring will continue. Other seasons are not critical to the eutrophication related issues in this reservoir. Siltation related impairments are most likely to be aggravated during spring and summer months due to the increased available rainfall and increased anthropogenic and livestock related activity in the watershed.

4. ALLOCATION OF POLLUTANT REDUCTION RESPONSIBILITY

Phosphorus is the primary pollutant of concern in Winfield City Lake and allocated under this TMDL. The general inventory of sources within the drainage does provide guidance as to areas of load reduction.

Point Sources: A current Wasteload Allocation of zero is established by this TMDL because of the lack of point sources in the watershed. Should future point sources be proposed in the watershed and discharge into the impaired segments, the current Wasteload allocation will be revised by adjusting current load allocations to account for the presence and impact of these new point source dischargers.

Nonpoint Sources: Water quality violations are predominantly due to nonpoint source pollutants. Reduction of total phosphorus levels to below 32 ppb in the lake should protect water quality and maintain the designated uses. To reduce total phosphorus concentrations to this level will require a reduction of loading by 2,348 lbs/year including the defined margin of safety. This reduction is equivalent to a watershed load of 4,782 pounds per year and an atmospheric load of 95 pounds per year. Allocating load reductions to various nonpoint sources within the watershed would require a detailed characterization of the watershed loading sources. Due to the lack of available data to conduct this kind of allocation, this TMDL declines to attempt any specific sourcing within the watershed, and defer to local knowledge regarding areas of critical need in implementation of this TMDL.

Defined Margin of Safety: The margin of safety provides some hedge against the uncertainty of variable annual total phosphorus loading. The margin of safety will be to provide capacity for 10% additional reduction from the annual load modeled to produce adequate water quality. This corresponds to an additional reduction below the total annual load (5,419 lbs) by 542 pounds of total phosphorus per year.

Winfield City Lake TP Load Allocations	Lbs/year
Waste Load Allocation	0
Atmospheric Deposition	95
Load Allocation	4,782
Margin of Safety	542
Total Annual Load	5,419

Table 7- Annual load allocations for Winfield City Lake.

State Water Plan Implementation Priority: Because this water is a public drinking water supply source, and is likely to experience some addition risk from zebra mussels, the Winfield City Lake TMDL will be a **High Priority** for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Lower Walnut Watershed (HUC 8: 11030018) with a priority ranking of 42 (Medium Priority for restoration).

Priority Areas: Implementation of land use practices should be targeted to those areas within 300 feet of Timber Creek.

5. IMPLEMENTATION

Desired Implementation Activities

Implementation should proceed with a focus on adaptive management. Initial areas of focus include reduced resuspension of existing sediment from watercraft wave action, identification of areas where unstable streambanks may be contributing to sediment and nutrient loading, detection and elimination of concentrated manure, alternative watering sites or livestock exclusion from streams and ponds, and detection and elimination of failing sanitary waste systems in the watershed. As time proceeds tracking the success of implementation measures should guide future implementation efforts to management practices showing the greatest reduction in loading.

There is a good potential for reducing pollutant loads to this lake through the use of best management practices. Some of the recommended agricultural practices are as follows:

1. Implement soil sampling to recommend appropriate fertilizer applications on cropland.
2. Maintain conservation tillage and contour farming to minimize cropland erosion.
3. Place highly erodible areas into permanent cover, including CRP enrollment.
4. Install grass buffer strips along intermitent streams.
5. Reduce activities within riparian areas.
6. Implement nutrient management plans to manage manure application to land.
7. Provide alternate water sources for livestock, and fence stream channels.

Implementation Programs Guidance

Non-Point Source Pollution Technical Assistance - KDHE

a. Support Section 319 demonstration projects for reduction of siltation runoff from agricultural or road construction activities

b. Provide technical assistance on practices geared to establishment of vegetative buffer strips.

c. Provide technical assistance on road construction activities in vicinity of streams.

d. Support the development, assessment, planning and implementation of a developing WRAPS to comprehensively reduce the loading and delivery of pesticides, sediment and nutrients to the stream system throughout its watershed.

Water Resource Cost Share & Non-Point Source Pollution Control Programs - SCC

a. Apply conservation farming practices, including terraces and waterways

b. Provide sediment control practices to minimize erosion and sediment transport

Riparian Protection Program - SCC

a. Establish or reestablish natural riparian systems, including vegetative filter strips and streambank vegetation.
b. Develop riparian restoration projects

Buffer Initiative Program - SCC

a. Install grass buffer strips near streams.
b. Leverage Conservation Security Program to hold riparian land out of production.

CRP Enrollment- NRCS

a. Enroll highly erodable lands in the conservation reserve program.

Extension Outreach and Technical Assistance - Kansas State University

a. Educate agricultural producers on sediment and pasture management
b. Provide technical assistance on buffer strip design and minimizing cropland runoff

Zebra Mussel Program- KDWP

a. Provide assistance for management of zebra mussel populations when possible.
b. Support local education efforts to raise awareness of zebra mussel problems

Time Frame for Implementation: Conversion of cropland to grasses within a 300 foot buffer along Timber Creek should occur through 2013. During 2008-2013 monitoring of in-lake conditions shall continue and show improved levels of ambient TP and chlorophyll a.

Delivery Agents: The primary delivery agents for program participation will be the Butler & Cowley County Conservation Districts for programs of the State Conservation Commission and the Natural Resources Conservation Service. Producer outreach and awareness will be delivered by Kansas State Extension. The Kansas Department of Health and Environment shall continue to monitor lake conditions.

Targeted Participants: Primary participants for implementation of best management practices will be agricultural producers within the drainage of the lake and the City of Winfield.

Milestone for 2013: The year 2013 marks the midpoint of the ten-year implementation window for the watershed. At that point in time, sampled data from Winfield City Lake will be reexamined to confirm the impaired status of the lake. Should impairment remain, more aggressive techniques will be examined to remove potential sources of sediment and nutrients from the lake.

Reasonable Assurances:

Authorities: The following authorities may be used to direct activities in the watershed to reduce pollutants.

1. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage

and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

2. K.S.A. 2-1915 empowers the State Conservation Commission to develop programs to assist the protection, conservation and management of soil and water resources in the state, including riparian areas.

3. K.S.A. 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control nonpoint source pollution.

4. K.S.A. 82a-901, et seq. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.

5. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan.*

6. The *Kansas Water Plan* and the Walnut Basin Plan provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

Funding: The State Water Plan Fund annually generates $16-18 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the *Kansas Water Plan*. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watersheds and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. This watershed and its TMDL is a **High Priority** consideration. Priority should be given to activities which reduce loadings of phosphorus to the lake prior to 2013.

Effectiveness: Phosphorus reduction has proven effective at reducing chlorophyll concentrations in a wide range of lakes worldwide.

6. MONITORING

Further sampling should occur before 2013. The Kansas Department of Health and Environment is planning to survey the lake in 2008 and 2011.

7. FEEDBACK

Public Meetings: Public Meetings to discuss TMDLs in the Walnut Basin have been held since 2002. An active Internet Web site was established at http://www.kdheks.gov/tmdl/index.htm to convey information to the public on the general establishment of TMDLs in the Walnut Basin and these specific TMDLs.

Public Hearing: A Public Hearing on these Walnut Basin TMDLs was held in Winfield on July 22, 2008.

Basin Advisory Committee: The Walnut Basin Advisory Committee met to discuss these TMDLs on October 3, 2007 in El Dorado.

Milestone Evaluation: In 2013, evaluation will be made as to implementation of management practices to minimize the nonpoint source runoff contributing to this impairment. Subsequent decisions will be made regarding the implementation approach, priority of allotting resources for implementation and the need for additional or follow up implementation in this watershed at the next TMDL cycle for this basin in 2013 with consultation from the Walnut Basin WRAPS teams.

Consideration for 303d Delisting: Winfield City Lake will be evaluated for delisting under Section 303d, based on the monitoring data over 2008-2015. Therefore, the decision for delisting will come about in the preparation of the 2016-303d list. Should modifications be made to the applicable water quality criteria during the implementation period, consideration for delisting, desired endpoints of this TMDL and implementation activities might be adjusted accordingly.

Incorporation into Continuing Planning Process, Water Quality, Management Plan and the Kansas Water Planning Process: Under the current version of the Continuing Planning Process, the next anticipated revision would come in 2008, which will emphasize implementation of WRAPS activities. At that time, incorporation of this TMDL will be made into the WRAPS. Recommendations of this TMDL will be considered in the *Kansas Water Plan* implementation decisions under the State Water Planning Process for Fiscal Years 2008-2015.

Developed May 20, 2009

Appendix A- BATHTUB TP Model Input and Output

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.8636	0.0
Evaporation (m)	1.3	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	10	0.50
Total N	730	0.50
Ortho P	10	0.50
Inorganic N	730	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	1	2ND ORDER, AVAIL P
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	2	P, LIGHT, T
Secchi Depth	1	VS. CHLA & TURBIDITY
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Segname 1	0	1	4.3	7	4.8	5	0	7	0	0.96	0	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	38	0.5	438	0.5	12	0.5	0.796	0.5	388	0.5	20	0.5	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Trib 1	1	1	166	21	0.5	0	0.5	154	0.5	1610	0.5	20	0.5	805	0.5

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.400	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.300	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Overall Water & Nutrient Balances

Overall Water Balance **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Trib 1	166.0	21.0	1.10E+02	0.50	0.13
PRECIPITATION				4.3	3.7	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				166.0	21.0	1.10E+02	0.50	0.13
***TOTAL INFLOW				170.3	24.7	1.10E+02	0.42	0.15
ADVECTIVE OUTFLOW				170.3	19.1	1.10E+02	0.55	0.11
***TOTAL OUTFLOW				170.3	19.1	1.10E+02	0.55	0.11
***EVAPORATION					5.6	0.00E+00	0.00	

Overall Mass Balance Based Upon Component: **Predicted TOTAL P** **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr	Load **lbs/year**
1	1	1	Trib 1	3234.0	98.7%	5.23E+06	100.0%	0.71	154.0	19.5	7129.741
PRECIPITATION				43.0	1.3%	4.62E+02	0.0%	0.50	11.6	10.0	94.79866
TRIBUTARY INFLOW				3234.0	98.7%	5.23E+06	100.0%	0.71	154.0	19.5	7129.741
***TOTAL INFLOW				3277.0	100.0%	5.23E+06	100.0%	0.70	132.6	19.2	7224.54
ADVECTIVE OUTFLOW				721.5	22.0%	2.34E+05		0.67	37.7	4.2	1590.678
***TOTAL OUTFLOW				721.5	22.0%	2.34E+05		0.67	37.7	4.2	1590.678
***RETENTION				2555.5	78.0%	3.47E+06		0.73			5633.862

Overflow Rate (m/yr)	4.4	Nutrient Resid. Time (yrs)	0.3466
Hydraulic Resid. Time (yrs)	1.5740	Turnover Ratio	2.9
Reservoir Conc (mg/m3)	38	Retention Coef.	0.780

PREDICTED CONCENTRATIONS:

Variable Segment-->	**1**
TOTAL P MG/M3	37.7
TOTAL N MG/M3	438.0
C.NUTRIENT MG/M3	20.3
CHL-A MG/M3	11.7
SECCHI M	0.8
ORGANIC N MG/M3	495.5
TP-ORTHO-P MG/M3	39.4
HOD-V MG/M3-DAY	117.2
MOD-V MG/M3-DAY	98.2
ANTILOG PC-1	232.7
ANTILOG PC-2	6.9
(N - 150) / P	7.6
INORGANIC N / P	1.0
TURBIDITY 1/M	1.0
ZMIX * TURBIDITY	4.8
ZMIX / SECCHI	6.3
CHL-A * SECCHI	9.3
CHL-A / TOTAL P	0.3
FREQ(CHL-a>10) %	47.6
FREQ(CHL-a>20) %	11.9
FREQ(CHL-a>30) %	3.3
FREQ(CHL-a>40) %	1.1
FREQ(CHL-a>50) %	0.4
FREQ(CHL-a>60) %	0.2
CARLSON TSI-P	56.5
CARLSON TSI-CHLA	54.7
CARLSON TSI-SEC	63.2

Appendix B- BATHTUB TP Reduction Model Input and Output

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.8636	0.0
Evaporation (m)	1.3	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	10	0.50
Total N	730	0.50
Ortho P	10	0.50
Inorganic N	730	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	1	2ND ORDER, AVAIL P
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	2	P, LIGHT, T
Secchi Depth	1	VS. CHLA & TURBIDITY
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Segname 1	0	1	4.3	7	4.8	5	0	7	0	0.96	0	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	38	0.5	438	0.5	12	0.5	0.796	0.5	388	0.5	20	0.5	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Trib 1	1	1	166	21	0.5	0	0.5	115	0.5	1207	0.5	20	0.5	604	0.5

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.400	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.300	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Trib 1	166.0	21.0	1.10E+02	0.50	0.13
PRECIPITATION				4.3	3.7	0.00E+00	0.00	0.86
TRIBUTARY INFLOW				166.0	21.0	1.10E+02	0.50	0.13
***TOTAL INFLOW				170.3	24.7	1.10E+02	0.42	0.15
ADVECTIVE OUTFLOW				170.3	19.1	1.10E+02	0.55	0.11
***TOTAL OUTFLOW				170.3	19.1	1.10E+02	0.55	0.11
***EVAPORATION					5.6	0.00E+00	0.00	

Overall Mass Balance Based Upon Component: **Predicted TOTAL P** — **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr	Load **lbs/year**
1	1	1	Trib 1	2415.0	98.3%	2.92E+06	100.0%	0.71	115.0	14.5	5324.157
PRECIPITATION				43.0	1.7%	4.62E+02	0.0%	0.50	11.6	10.0	94.79866
TRIBUTARY INFLOW				2415.0	98.3%	2.92E+06	100.0%	0.71	115.0	14.5	5324.157
***TOTAL INFLOW				2458.0	100.0%	2.92E+06	100.0%	0.69	99.5	14.4	5418.956
ADVECTIVE OUTFLOW				613.1	24.9%	1.68E+05		0.67	32.1	3.6	1351.566
***TOTAL OUTFLOW				613.1	24.9%	1.68E+05		0.67	32.1	3.6	1351.566
***RETENTION				1844.9	75.1%	1.82E+06		0.73			4067.39

Overflow Rate (m/yr)	4.4	Nutrient Resid. Time (yrs)	0.3926
Hydraulic Resid. Time (yrs)	1.5740	Turnover Ratio	2.5
Reservoir Conc (mg/m3)	32	Retention Coef.	0.751

PREDICTED CONCENTRATIONS:

Variable Segment-->	**1**
TOTAL P MG/M3	32.1
TOTAL N MG/M3	438.0
C.NUTRIENT MG/M3	19.2
CHL-A MG/M3	10.2
SECCHI M	0.8
ORGANIC N MG/M3	461.6
TP-ORTHO-P MG/M3	36.8
HOD-V MG/M3-DAY	109.4
MOD-V MG/M3-DAY	91.7
ANTILOG PC-1	201.1
ANTILOG PC-2	6.4
(N - 150) / P	9.0
INORGANIC N / P	1.0
TURBIDITY 1/M	1.0
ZMIX * TURBIDITY	4.8
ZMIX / SECCHI	6.1
CHL-A * SECCHI	8.4
CHL-A / TOTAL P	0.3
FREQ(CHL-a>10) %	39.0
FREQ(CHL-a>20) %	8.1
FREQ(CHL-a>30) %	2.0
FREQ(CHL-a>40) %	0.6
FREQ(CHL-a>50) %	0.2
FREQ(CHL-a>60) %	0.1
CARLSON TSI-P	54.2
CARLSON TSI-CHLA	53.4
CARLSON TSI-SEC	62.8

Appendix C– Conversion to Daily Loads as Regulated by EPA Region VII

The TMDL has estimated annual average loads for TP that if achieved should meet the water quality targets. A recent court decision often referred to as the "Anacostia decision" has dictated that TMDLs include a "daily" load (Friend of the Earth, Inc v. EPA, et al.).

Expressing this TMDL in daily time steps could be misleading to imply a daily response to a daily load. It is important to recognize that the growing season mean chlorophyll *a* is affected by many factors such as: internal lake nutrient loading, water residence time, wind action and the interaction between light penetration, nutrients, sediment load and algal response.

To translate long term averages to maximum daily load values, EPA Region 7 has suggested the approach describe in the Technical Support Document for Water Quality Based Toxics Control (EPA/505/2-90-001)(TSD).

Maximum Daily Load (MDL) = (Long-Term Average Load) * $e^{[Z\sigma - 0.5\sigma^2]}$

where $\sigma^2 = \ln(CV^2 + 1)$

CV = Coefficient of variation = Standard Deviation / Mean

Z = 2.326 for 99th percentile probability basis

LTA= Long Term Average

LA= Load Allocation

MOS= Margin of Safety

Parameter	LTA-lbs/year	CV	$e^{[Z\delta-0.5\delta\text{^}2]}$	MDL- lbs/day	LA- lbs/day	MOS (10%)- lbs/day
TP Annual Load	5,419	0.5	2.683671435	40	36	4
TP Load Allocation	4,782	0.5	2.683671435	35	32	4
TP Margin of Safety	542	0.5	2.683671435	4	4	0.40
TP Atmospheric Deposition	95	0.5	2.683671435	0.70	0.63	0.07

Maximum Daily Load Calculation

Maximum Daily Load = (Long-Term Average Load) * $e^{[Z\sigma - 0.5\sigma^2]}$

where $\sigma^2 = \ln(CV^2 + 1)$

CV = Coefficient of variation (0.5)

Z = 2.326 for 99th percentile probability basis

Annual TP Load = 5419 lbs/yr

Maximum Daily TP Load = [(5419 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.412) - 0.5*(0.412)^2]}$

= 40 lbs/day

Margin of Safety (MOS) for Daily Load

Annual TP MOS = 542 lbs/yr

Daily TP MOS = [(542 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.472) - 0.5*(0.472)^2]}$

= 4 lbs/day

Source- *Technical Support Document for Water Quality-based Toxics Control (EPA/505/2-90-001)*

Appendix D- Model Calibration and Input Data Sources

Universal Data-

All lake water quality data is the numeric average of all data collected by KDHE in the epilimnion of the lake. CV arbitrarily assigned to 0.5.

Precipitation data is from the PRISM group average values for precipitation from 1971-2000. http://www.prism.oregonstate.edu/index.phtml

Evaporation data from USGS Hydrological Estimates for Kansas Lakes.

Atmospheric loads of TP, TN, Ortho-P and DIN are BATHTUB default values.

Model Options are all BATHTUB default options.

Lake morphometry data calculated from KBS bathymetry data using ArcGIS 9.2.

Mixed layer depth is the average depth as measured by KDHE during lake sampling events.

Non-algal turbidity calculated by BATHTUB.

Lake segment calibration factors are all BATHTUB defaults.

Drainage area calculated using ArcGIS 9.2.

Flow estimates for inflow from USGS Hydological Estimates for Kansas Lakes.

Model decay rates were adjusted to calibrate model results to specific observed conditions in Winfield City Lake. Total phosphorus, total nitrogen and chl-a model decay rates were adjusted within ranges recommended in EPA Region 7 sponsored training on BATHTUB model development by Tetra-Tech. Models decay rates were considered acceptable when t-test statistics were no longer significant at an alpha of 0.05.

Current Conditions Tributary Data-

Inflow-

Total phosphorus inflow concentration estimated based on measured data from Fall River Lake. Concentrations were adjusted by watershed size to better approximate the likely conditions in the inflowing streams. Annual load estimates per unit area were divided into the total annual estimated inflow to determine average concentration for model development.

Total nitrogen inflow concentration estimated based on measured data from Fall River Lake. Model results suggested that no adjustment for watershed size was needed for this parameter. Annual load estimates per unit area were divided into the total annual estimated inflow to determine average concentration for model development.

Ortho-p assigned to KDHE practical quantitation limit.

DIN assign a value of half of total nitrogen concentration.

Load Reduction Condition Tributary Data-

Inflow-

Nutrient concentrations were adjusted in a pair-wise TP/TN concurrent reduction scheme and the model was re-run until acceptable chlorophyll concentrations were obtained. Inorganic nitrogen and ortho-P were reduced concurrently and at approximately the same rate as a percentage of total concentration.

Appendix E: STEPL Model Inputs and outputs

State	County	Weather Station (for rain correction factors)
Kansas		KS FALL RIVER LAKE

1. Input watershed land use area (ac) and precipitation (in)

									Rain correction factors		
									0.886	0.498	
Watershed	Urban	Cropland	Pastureland	Forest	User Defined	Feedlots	Feedlot Percent Paved	Total	Annual Rainfall	Rain Days	Avg. Rain/Event
W1	0	5489	29286	2293	1597	0	0-24%	38665	35.01	83	0.750

2. Input agricultural animals

Watershed	Beef Cattle	Dairy Cattle	Swine (Hog)	Sheep	Horse	Chicken	Turkey	Duck	# of months manure applied
W1	3764	0	0	0	0	0	0	0	0
Total	3764	0	0	0	0	0	0	0	

3. Input septic system and illegal direct wastewater discharge data

Watershed	No. of Septic Systems	Population per Septic System	Septic Failure Rate, %	Wastewater Direct Discharge, # of People	Direct Discharge Reduction, %
W1	0	2.43	10	0	0

4. Modify the Universal Soil Loss Equation (USLE) parameters

Watershed	Cropland					Pastureland					Forest					User Defined				
	R	K	LS	C	P	R	K	LS	C	P	R	K	LS	C	P	R	K	LS	C	P
W1	150.000	0.260	0.193	0.244	0.993	150.000	0.260	0.568	0.020	1.000	150.000	0.260	0.193	0.003	1.000	150.000	0.260	0.193	0.020	1.000

Optional Data Input:

5. Select average soil hydrologic group (SHG), SHG A = highest infiltration and SHG D = lowest infiltration

Watershed	SHG A	SHG B	SHG C	SHG D	SHG Selected	Soil N conc.%	Soil P conc.%	Soil BOD conc.%
W1					A	0.050	0.010	0.100

6. Reference runoff curve number (may be modified)

SHG	A	B	C	D
Urban	83	89	92	93
Cropland	67	78	85	89
Pastureland	30	69	79	84
Forest	30	60	73	79
User Defined	50	70	80	85

6a. Detailed urban reference runoff curve number (may be modified)

Urban\SHG	A	B	C	D
Commercial	89	92	94	95
Industrial	81	88	91	93
Institutional	81	88	91	93
Transportatior	98	98	98	98
Multi-Family	77	85	90	92
Single-Family	57	72	81	86
Urban-Cultivat	67	78	85	89
Vacant-Develc	77	85	90	92
Open Space	49	69	79	84

7. Nutrient concentration in runoff (mg/l)

Land use	N	P	BOD
1. L-Croplanc	**1.9**	**0.7**	**4**
1a. w/ manure	8.1	2	12.3
2. M-Croplanc	**2.9**	**0.9**	**6.1**
2a. w/ manure	12.2	3	18.5
3. H-Croplanc	**4.4**	**1.1**	**9.2**
3a. w/ manure	18.3	4	24.6
4. Pasturelan	**5**	**0.25**	**13**
5. Forest	**0.2**	**0.02**	**0.5**
6. User Defin	**0**	**0**	**0**

7a. Nutrient concentration in shallow groundwater (mg/l) (may be modified)

Landuse	N	P	BOD
Urban	1	0.01	0
Cropland	1.44	0.063	0
Pastureland	1.44	0.005	0
Forest	0.11	0.005	0
Feedlot	6	0.07	0
User-Defined	0	0	0

8. Input or modify urban land use distribution

Watershed	Urban Area (ac.)	Commercial %	Industrial %	Institutional %	Transportation %	Multi-Family %	Single-Family %	Urban-Cultivated %	Vacant (developed)	Open Space %	Total % Area
W1	0	0	0	0	0	0	0	0	0	100	100

9. Input irrigation area (ac) and irrigation amount (in)

Watershed	Total Cropland (ac)	Cropland: Acres Irrigated	Water Depth (in) per Irrigation - Before BMP	Water Depth (in) per Irrigation - After BMP	Irrigation Frequency (#/Year)
W1	5489	0	0	0	0

Input Ends Here.

Total Load This is the summary of annual nutrient and sediment load for each subwatershed. This sheet is initially protected.

1. Total load by subwatershed(s)

Watershed	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)	N Reduction	P Reduction	BOD Reduction	Sediment Reduction	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)	%N Reduction	%P Reduction	%BOD Reduction	%Sed Reduction
	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	lb/year	lb/year	lb/year	t/year	%	%	%	%
W1	56841.0	7367.3	138825.8	2625.8	0.0	0.0	0.0	0.0	56841.0	7367.3	138825.8	2625.8	0.0	0.0	0.0	0.0
Total	56841.0	7367.3	138825.8	2625.8	0.0	0.0	0.0	0.0	56841.0	7367.3	138825.8	2625.8	0.0	0.0	0.0	0.0

2. Total load by land uses (with BMP)

Sources	N Load (lb/yr)	P Load (lb/yr)	BOD Load (lb/yr)	Sediment Load (t/yr)
Urban	0.00	0.00	0.00	0.00
Cropland	13976.04	4768.80	29185.57	1128.92
Pastureland	42674.73	2572.95	109197.47	1464.03
Forest	136.14	14.78	334.52	5.83
Feedlots	0.00	0.00	0.00	0.00
User Defined	54.13	10.83	108.25	27.06
Septic	0.00	0.00	0.00	0.00
Gully	0.00	0.00	0.00	0.00
Streambank	0.00	0.00	0.00	0.00
Groundwater	0.00	0.00	0.00	0.00
Total	56841.04	7367.35	138825.81	2625.85